viscosity. Further mixing was done using the muller with 500 grams of weight for approximately 6 passes at 25 revolutions per pass. The finished pastes were then transferred to containers until needed.

B. Single Sensor Fabrication

Some of the sensing chips were prepared using a single material and not arrays of sensing materials. The single sensing sample chips were made by screen printing an interdigitated electrode pattern with electrodes, which are 0.4" long and have a 0.008" spacing onto an alumina substrate (Coors Tek, 96% alumina, 1" x 1" x 0.025"). A semi-automatic screen printer (ETP Electro-dial, Series L-400) was used. The electrode paste (product #5715) is available from DuPont *i*Technologies. The electrode screen (Microcircuit Engineering Corporation) had an emulsion thickness of 0.5 mil. After printing, the parts were dried in a convection oven at 120°C for 10 minutes and then fired. Firing was done using a 10 zone belt furnace (Lindberg) with a cycle time of 30 minutes and a peak temperature of 850°C for 10 minutes. The sensor material was then screen printed on the substrate using a screen (Microcircuit Engineering Corporation) with an open area 0.5" x 0.5". This screen had an emulsion thickness of 1.0 mil. After the sensor material was printed the part was dried in a convection oven at 120°C for 10 minutes. At this point the part was fired in air to 850°C for 10-45 minutes using a Lindberg tube furnace.

C. Sensor Array Fabrication

A variety of electrode and sensor configurations can be used to acquire the AC impedance data of the sensor array. Described immediately below is the fabrication of a 12-material array.

The sensor array chip was made by screen printing an electrode pattern (Figure 3) onto an alumina substrate (Coors Tek, 96% alumina, 2.5" x 0.75" x 0.040"). A semi-automatic screen printer (ETP Electro-

dial, Series L-400) was used. The electrode paste (product #4597) is available from DuPont *i*Technologies. The electrode screen (Microcircuit Engineering Corporation) had an emulsion thickness of 0.4 mil. Note in Figure 3 that two of the sensor pads are in parallel, so that only six unique sensor material measurements can be made from this electrode configuration. After printing, the parts were dried in a convection oven at 130°C for 10 minutes and then fired. Firing was done in air using a 10 zone belt furnace (Lindberg) with a cycle time of 30 minutes and a peak temperature of 850°C for 10 minutes. After the electrodes were fired onto the substrate a dielectric (DuPont *i*Technologies, product #QM44) pattern, shown in Figure 3, was screen printed over the electrodes with a screen (Microcircuit Engineering Corporation), having an emulsion thickness of 1.0 mil. The parts were then dried at 130°C for 10 minutes and fired using the same firing cycle as described above. At this point, each sensor material was screen printed on the substrate into the wells of the dielectric using the screen (Microcircuit Engineering Corporation), shown in Figure 3. This screen had an emulsion thickness of 1.0 mil. After each sensor material was printed the part was dried in a convection oven at 130°C for 10 minutes. After all of the sensor materials (6) were applied to this side of the sensor, the part was fired using the same firing cycle as described above. After this firing step, the above printing, drying and firing steps were repeated on the back side of the substrate to add 6 more sensor materials to the array chip.

D. <u>AC Impedance Measurements</u>

For single sensor material samples, a 1.2" platinum wire was connected to each of the electrodes on the samples with stainless steel screws. The ends of the platinum wires were then connected to 0.127" diameter inconel wires that run to the exterior of the test chamber. The entire lengths of the inconel wires

were encased in aluminum oxide and grounded inconel tubing to eliminate interference from electromagnetic fields present in the furnace. The inconel tubes were welded into a stainless steel flange that was mounted on the end of a closed-one-end fused quartz reactor that is 4" in diameter and 24" long. The quartz reactor was wrapped with grounded stainless steel screen also to eliminate electromagnetic interference from the furnace. The entire chamber assembly was placed in the cavity of a hinged Lindberg tube furnace and the furnace was closed.

The samples were connected to the dielectric interface (Solartron 1296) and frequency response analyzer (Solartron 1260) using ten pairs of coaxial cables (one pair per sample) which ran from the inconel wires on the furnace exterior to a switch (Keithley 7001 containing two Keithley 7062 high frequency cards) and one pair of coaxial cables from the switch to the interface and analyzer. The switch, dielectric interface and frequency analyzer were all computer controlled.

The gas flows into the quartz chamber were regulated using a computer controlled system comprised of 4 independent flowmeters (MKS product #1179) and multi gas controller (MKS product #647B). The temperature of the furnace was determined using a computer controlled fuzzy logic controller (Fuji PYX).

After the samples were loaded into the furnace, the quartz reactor was purged with a synthetic air mixture during heating of the furnace. After the furnace was equilibrated at the measurement temperature, the gas concentrations ($N_2$, $O_2$, 1%CO/99% $N_2$, and 1% $NO_2$/99% $N_2$ were set to the desired values and sufficient time was allowed for the equilibration of the atmosphere in the reactor. At this point the AC impedance measurements (1 Hz to 1 MHz) from each sample were measured sequentially. Then the gas concentrations were typically set to a new value, the